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(19) (CA) CANADIAN PATENT (12)

(54) Reducing the Water and Solids Contents of Bitumen Froth Moving Through the Launder of a Spontaneous Flotation Vessel

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1 "REDUCING THE WATER AND SOLIDS CONTENTS OF BITUMEN
2 FROTH MOVING THROUGH THE LAUNDER OF A
3 SPONTANEOUS FLOTATION VESSEL"

4 ABSTRACT OF THE DISCLOSURE

5 An aperture is formed in the bottom wall of the
6 launder. A downwardly extending container communicates with the
7 aperture. A weir is positioned immediately downstream of the
8 aperture. The container and weir combine to form a separator.
9 In the launder, free water and solids contaminants settle and
10 form a bottom layer of dirty water. The layer is diverted into
11 the container through the aperture and the weir temporarily
12 retains a small head of it. Temporary retention in the separator
13 therefore generates a vertical fluid column comprising an upper
14 layer of relatively clean froth and a lower layer of dirty water,
15 said layers having an ascertainable interface. The elevation of
16 the interface is monitored and contaminated fluid is withdrawn
17 from the container as underflow at a rate controlled to keep the
18 interface elevation substantially constant. The froth
19 overflowing the weir is reduced in water and solids relative to
20 the original froth issuing from the flotation vessel.

FIELD OF THE INVENTION

This invention relates to a process and apparatus for improving the quality of bitumen froth produced by spontaneous flotation in the course of extracting bitumen from oil sands using the hot water process. More particularly it relates to separating water and solids from bitumen froth, to thereby clean and upgrade the froth.

BACKGROUND OF THE INVENTION

Bitumen (a form of heavy oil) is commercially recovered from oil sand in Alberta. This recovery is achieved by mining the oil sand, extracting the bitumen from the oil sand in the form of froth, cleaning the froth product to remove contained water and solids, and upgrading the bitumen to produce a variety of oil products. Extraction is achieved using a process referred to in the industry as the hot water process. This process is described in considerable detail in prior art patents and in the technical literature. A short summary of the process is given below.

To better understand the hot water process, it is helpful to know about the nature of oil sand itself. Oil sand comprises grains of sand which are individually sheathed or wetted with a very thin layer of connate water. Small flecks of bitumen are located in the interstices between the water-wet grains. Minute clay particles (termed "fines") are dispersed in the connate water phase.

In general, the hot water process involves slurring the as-mined oil sand in hot water with surfactant-forming caustic and relying on a combination of heating, agitation, and



1 surfactant actions to disperse the bitumen from the solids and
2 into the aqueous phase of the slurry. At this point, bitumen
3 flecks coalesce and some become attached to air bubbles, so that
4 the aerated bitumen floats as a froth. The froth is then
5 recovered.

6 The composition of the as-mined oil sand is variable.
7 The oil, water and solids contents of oil sand processed at
8 applicants' plant can typically vary as follows:

9 TABLE I

10	oil:	6 to 18% by wt.
11	water:	0 to 14% by wt.
12	fines (-44u)	10 to 75% by wt.
13	total solids:	70 to 90% by wt.

14 This variability in composition leads to wide swings
15 in the processability of the feed when using the hot water
16 process. A "rich" oil sand, high in oil and low in fines, will
17 give a high yield of good quality extraction product; a "lean"
18 oil sand, low in oil and high in fines, will give a relatively
19 low yield of relatively poor quality product. By way of example,
20 Table II sets forth typical values for the composition of oil
21 sand feed, for rich and lean ores of sufficient quality to be
22 processed, and the recovery and composition of the primary froth
23 product which one would typically obtain.

TABLE II

1				
2	Lean Oil Sand:		Percent Oil Recovered As:	
3	Oil	6%	Primary Froth	65%
4	Water	11%	Froth Composition:	
5	Fines	21%	Oil	55%
6	Solids	83%	Water	34%
7			Solids	11%

8	Rich Oil Sand:		Percent Oil Recovered As:	
9	Oil	12%	Primary Froth	92%
10	Water	3%	Froth Composition:	
11	Fines	14%	Oil	65%
12	Solids	85%	Water	27%
13			Solids	8%

14 One of the disadvantages of producing a froth product
 15 stream having such wide swings in its compositional make-up is
 16 that the downstream equipment has to be sized to accommodate the
 17 worst case. In addition, constantly adjusting the downstream
 18 processing for optimization involves difficulty.

19 So any simple and effective means for reducing the
 20 water and solids contents of the froth and smoothing out the
 21 froth composition variations, would be desirable.

22 At this point it is useful to provide a short
 23 description, in greater detail, of the hot water extraction
 24 process, as practised at the plant of the present assignees, to
 25 put the invention into context. The process involves:

26 - Mixing as-mined oil sand with hot water and a
 27 small amount of NaOH in a rotating horizontal drum
 28 for a period of several minutes to produce an

1 aqueous slurry of thick consistency. Steam is
2 sparged into the slurry to develop an exit
3 temperature of about 180°F. In this slurring
4 step, the lumps of oil sand are ablated, the
5 bitumen flecks are heated and the NaOH reacts in
6 situ with bitumen moieties to form surfactants.
7 The bitumen flecks become liberated from the
8 solids and are dispersed into the aqueous phase.
9 In addition, air bubbles are entrained into the
10 slurry. Some of the bitumen flecks coalesce and
11 coat air bubbles;

12 - The slurry is then diluted with additional hot
13 water and is temporarily retained under quiescent
14 conditions in a large, cylindrical, conical-
15 bottomed, open-topped vessel referred to as a
16 primary separation vessel (hereafter "PSV"). In
17 the PSV, "spontaneous flotation" of the bitumen
18 occurs. More particularly, buoyant bitumen floats
19 to form an oily froth. This froth, (called
20 "primary froth"), overflows the upper lip of the
21 PSV and is conveyed away from the vessel in a
22 downwardly sloping, broad channel, referred to as
23 a launder. As the froth is forming in the PSV,
24 the coarse solids settle and are discharged from
25 the base of the vessel. This stream of coarse
26 solids, associated with some water and a small
27 amount of bitumen, is called "PSV tailings". Some
28 residual, insufficiently buoyant oil remains in

1 the watery main body of the PSV contents - this
2 fluid is referred to as "PSV middlings".

3 - The PSV middlings and PSV tailings are combined
4 and are fed into a vessel referred to as the
5 tailings oil recovery vessel (hereafter "TORV").
6 This is a cone settler, into which the PSV
7 middlings and tailings are fed and are caused to
8 move outwardly and laterally from a central feed
9 point. The feed is contacted from below by an
10 upwelling aerated stream of PSV middlings. A
11 second yield of bitumen froth forms and overflows
12 the vessel rim and is conveyed away in a launder.
13 In the vessel, the coarse solids settle, are
14 concentrated in the narrowing lower end of the
15 cone, and are discharged as tailings. (The TORV
16 process is described in greater detail in U.S.
17 Patent 4,545,892.) The process occurring in the
18 TORV is also characterized as spontaneous
19 flotation;

20 - As the last step in the extraction process, the
21 middlings from the TORV are fed to a bank of
22 induced flotation cells, in which the feed is
23 vigorously sub-aerated and agitated and from which
24 a third froth stream is recovered. This froth
25 (termed "secondary froth") is cleaned by settling
26 out some contained water and solids by temporarily
27 retaining the mixture in a settling tank.

1 The various froth streams are combined, deaerated,
2 diluted with naphtha, and then centrifuged, to remove contained
3 water and solids. Centrifuging involves passing the deaerated
4 and diluted froth through two stages of centrifugation, using
5 scroll and disc centrifuges.

6 As indicated, the various froth products (PSV, TORV and
7 secondary) contain water and solids as contaminants. It is the
8 concentration of these contaminants that can vary widely,
9 depending on the grade of the oil sand originally fed to the
10 process.

11 SUMMARY OF THE INVENTION

12 The present invention has been developed as a result
13 of making the following observations:

- 14 - That bitumen froth issuing from a flotation
15 vessel, such as the PSV or TORV, contains discrete
16 water particles ranging in size from microscopic
17 flecks to pea-size globules;
18 - That, when in a gently sloped channel or launder,
19 some of the water particles migrate downwardly
20 through the froth body and collect and coalesce
21 along the bottom wall of the channel in the form
22 of a discrete, water-rich layer, which
23 additionally contains some settled solids.

24 Having observed this action, applicants have devised
25 a system wherein:

- 26 - The water-rich bottom layer is at least partly
27 diverted through an aperture or outlet in the
28 channel bottom wall and is temporarily retained

1 in an upstanding container positioned beneath the
2 channel;

3 - In addition, a weir is positioned immediately
4 downstream of the diversion aperture. The weir
5 extends transversely across the channel and
6 functions to keep a small head of the dirty water
7 with its surface above the aperture;

8 - Thus a column of fluid comprising upper and lower
9 layers, having distinctive compositions and a
10 discernible interface, is formed in the separator
11 consisting of the combination of the weir and
12 container. The upper layer is relatively clean
13 bitumen froth, containing some water and solids,
14 and the lower layer is mainly water containing
15 solids and traces/ of bitumen;

16 - The elevation of the interface is monitored; and
17 - A variable pump, controlling the rate of
18 withdrawal of fluid from the base of the
19 container, is operated in response to the location
20 of the interface so as to maintain the interface
21 at a substantially constant pre-determined level.

22 In a preferred feature, means are provided for
23 injecting make-up water into the lower end of the container
24 chamber. In the event that good quality oil sand is being
25 processed, the froth will contain solids but only a small
26 quantity of water. In this circumstance, it would only be
27 possible to drain water from the container at a slow rate,
28 otherwise the oil/water interface would be lowered to an
29 undesirable elevation. At such slow withdrawal rates, plugging

1 with solids becomes a problem. By adding water to the mainly
2 water layer in the container, as required, plugging can be
3 avoided by maintaining a desirable rate of water withdrawal.

4 As a result of implementing the foregoing system, it
5 has been found that the concentrations of water and solids in
6 bitumen froth can be reduced in a simple manner.

7 DESCRIPTION OF THE DRAWINGS

8 Figure 1 is a side view, partly broken away, showing
9 an assembly incorporating the invention, said assembly having
10 been used on a pilot plant basis to test the system;

11 Figure 2 is a plot showing the bitumen content of
12 sixteen samples of each of PSV and knock-out froth;

13 Figure 3 is a plot using the same data as Figure 2, but
14 modified to account for predicted sampling error; and

15 Figure 4 is a comparative plot for sixteen samples,
16 showing the improvement achieved in froth quality by using the
17 invention.

18 DESCRIPTION OF THE PREFERRED EMBODIMENT

19 Having noted that free water was associated with
20 bitumen froth flowing through the open-topped channel or launder
21 1 of a hot water process pilot plant spontaneous flotation vessel
22 or PSV 2, a downwardly extending container 3 was attached to the
23 bottom wall 4 of the launder. The container 3 communicated with
24 the launder passageway 5 by means of an aperture 6. A
25 transversely extending weir 7 was positioned across the
26 passageway 5, immediately downstream of the aperture 6. The weir
27 7 and container 3 together formed a separator. The container 3

1 was equipped with a drain line 8 and a variable discharge Moyno¹
2 pump 9. A water line 20, connected with a water source (not
3 shown), was provided to supply make-up water to the internal
4 chamber 21 of the container 3, when required. The froth/water
5 interface level 14 in the separator was monitored using an
6 interface level sensor 10. Specifically, an Endress and Hauser
7 FMC 480Z capacitance-type gauge was used. The pump 9 was
8 controlled using a Bailey Network 90 control assembly 11 in
9 response to the measurements taken by the sensor 10, to maintain
10 the interface level 14 substantially constant. The cleaned froth
11 16 overflowing the weir 7 was collected in a weigh tank 12.
12 Dirty water 15 collected in the chamber 21.

13 Froth samples were collected at the lip 13 of the PSV
14 2 and at the weigh tank 12. The bottom discharge stream of dirty
15 water from the container 3 was also sampled. Over 80 samples
16 were analyzed for oil, water and solids. Mass balance periods
17 of 20 minutes were conducted periodically. Mass flow rates of
18 the three streams were obtained during these periods.

19 Sixteen complete sets of data were accumulated. Figure
20 2 shows plots of quality (% bitumen) of both the PSV froth and
21 the knock-out froth collected in the weigh tank 12.

22 The data showed that, while in most cases knock-out
23 froth was improved relative to PSV froth, there were several
24 samples where the quality had actually decreased. These
25 unfavourable results were felt to be due to the highly variable
26 quality of the froth, which changes composition from moment to
27 moment. In addition, mass balances conducted on the separator
28 did not exhibit mass closure.

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1 In an effort to rationalize the results to achieve mass
2 closure, the software program MATBAL², available from CANMET,
3 was applied to the data. Measurement uncertainties were
4 assigned, based on applicants' years of experience operating the
5 pilot plant PSV. They were:

6 Froth:

7 bitumen - 3.5% uncertainty

8 solids - 10% uncertainty

9 Flowrates: 1% uncertainty.

10 The PSV froth and knock-out froth data, both modified
11 using MATBAL, are plotted in Figure 3. These rationalized
12 results indicated that knock-out froth quality is always equal
13 or superior to PSV froth quality, when the invention is
14 practised.

15 The scope of the invention is set forth in the claims
16 now following.

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1 THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
2 PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

3 1. In combination:

4 a bitumen flotation vessel for recovering bitumen froth
5 from an aqueous slurry of oil sand, said vessel having means for
6 conveying produced froth away from the vessel, said means
7 comprising a downwardly sloped channel having a bottom wall for
8 conveying the froth stream, whereby the froth passing along the
9 channel may form a stream and contained water and solids
10 contaminants in the froth may concentrate in a bottom layer of
11 dirty water forming part of the stream;

12 means forming an aperture in the channel bottom wall,
13 said aperture being positioned to divert the bottom layer of
14 dirty water;

15 a weir, extending transversely across the channel
16 immediately downstream of the aperture, for temporarily retaining
17 part of the froth;

18 a container extending downwardly from the channel
19 bottom wall, said container communicating at its upper end with
20 the aperture, said container having a discharge outlet at its
21 lower end, said container and weir combining to form a separator
22 adapted to temporarily retain the stream sufficiently long so
23 that it may form a bottom portion of dirty water and an upper
24 cleaned froth portion, said portions having a discernible
25 interface;

26 a discharge line and variable pump means, connected
27 with the container discharge opening, for removing said dirty
28 water from the container at a controlled rate;

1 means for monitoring the elevation of the interface;
2 and
3 means for controlling the pump means in response to the
4 interface elevation.

5 2. A method for reducing water and solids contaminant
6 concentrations in hot water process bitumen froth produced in a
7 flotation vessel, comprising:

8 conveying the froth in a downwardly sloping, elongate
9 channel extending from the vessel and having a bottom wall,
10 whereby water and solids contained in the stream settle to form
11 a bottom layer of dirty water;

12 said channel having an aperture formed in its bottom
13 wall and being associated with a container extending downwardly
14 from the aperture and a weir extending transversely across the
15 channel immediately downstream of the aperture, said container
16 communicating at its upper end with the aperture and being
17 connected at its bottom end with a discharge line and variable
18 pump, said container and weir combining to form a separator;

19 diverting at least part of the bottom layer of dirty
20 water through the aperture into the container and temporarily
21 retaining it therein;

22 temporarily retaining part of the balance of the froth
23 stream with the weir;

24 whereby the fluid entering the separator forms an upper
25 portion of relatively clean froth and a bottom portion of dirty
26 water, said portions having a discernible interface;

27 monitoring the level of the interface in the separator;

1 pumping dirty water from the base of the container
2 through the discharge line at a rate responsive to the elevation
3 of the interface, to maintain the elevation of the interface
4 substantially constant; and
5 recovering froth overflowing the weir, said froth
6 having a reduced water and solids content relative to the froth
7 originally produced from the flotation vessel.



Patent agent:
E. P. Johnson

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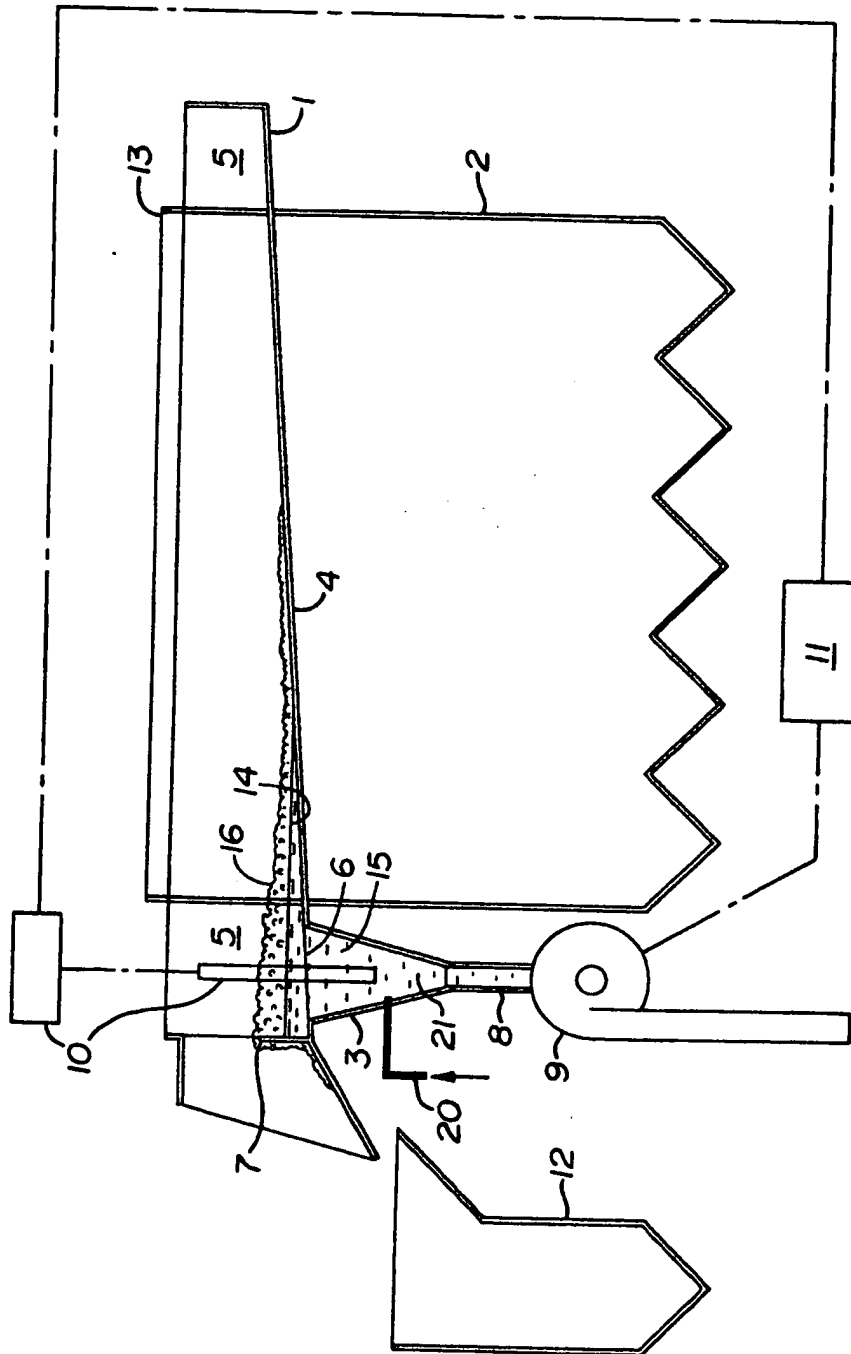


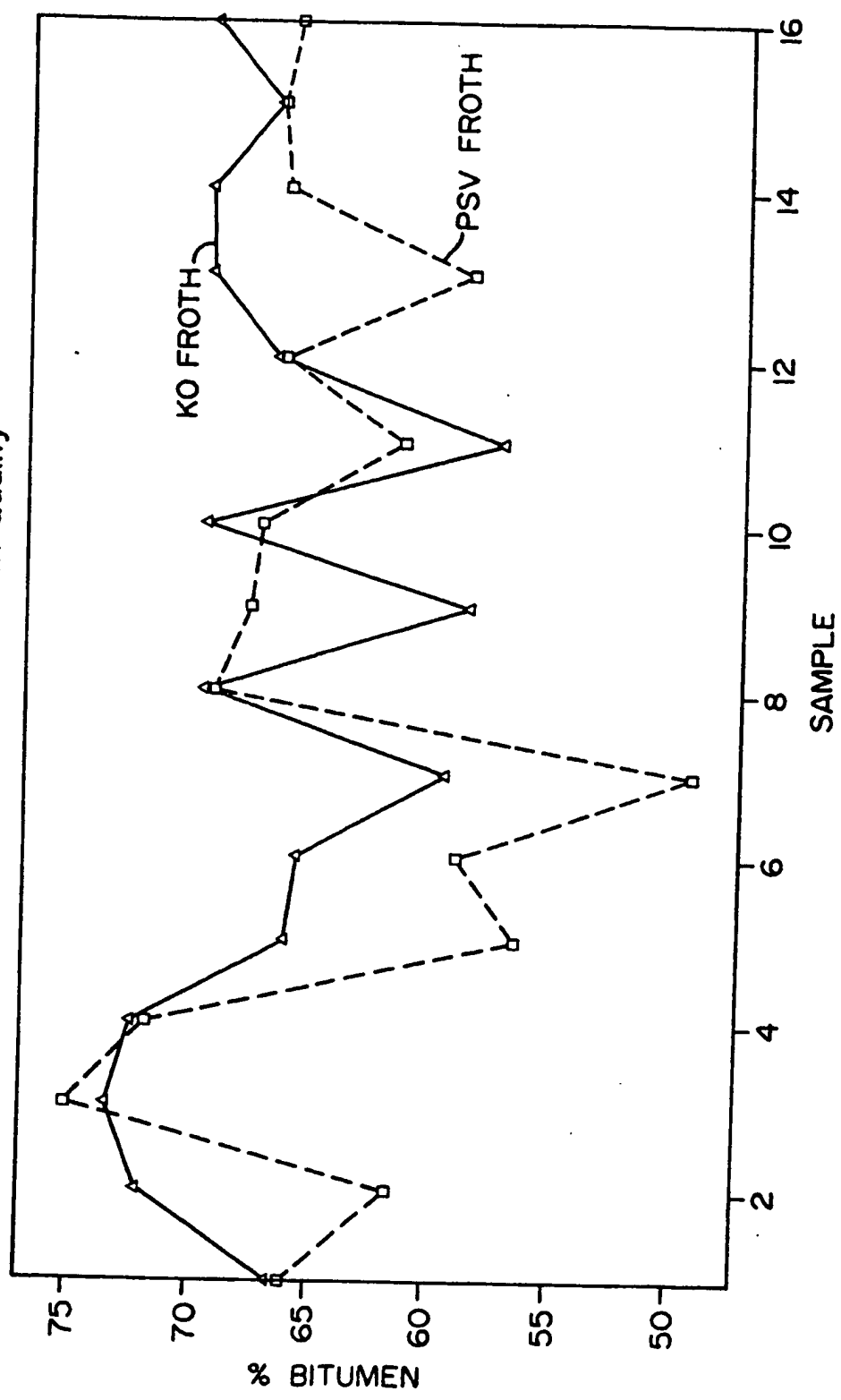
Fig. 1.

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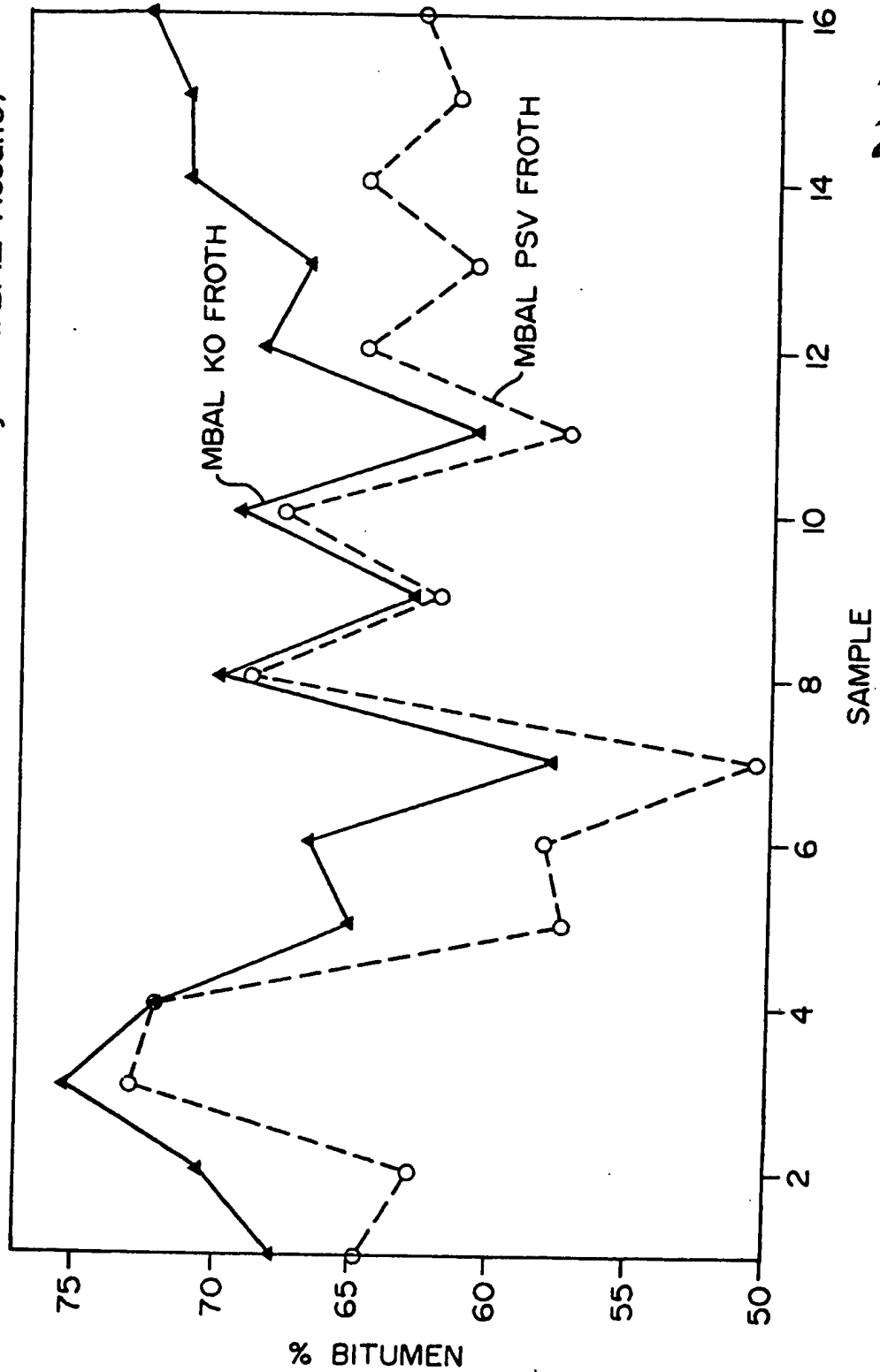
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Patent agent:
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Fig. 2. PSV and Water Knock-Out Froth Quality



Patent agent:

*E.P. Johnson***Fig. 3.** PSV and Water Knock-Out Froth Quality (MATBAL Results)

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Fig. 4. Froth Quality Improvement (Original and MATBAL Results)

